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Spatio-Temporal Urban Land Use/Cover Change Analysis in a Hill Station: The Case of Baguio City, Philippines

Ronald C. Estoque[a,b*], Yuji Murayama[a]

[a]Division of Spatial Information Science, Graduate School of Life and Environmental Sciences, University of Tsukuba, Japan
[b]Don Mariano Marcos Memorial State University, Philippines

Abstract

This study explores the spatial and temporal characteristics of land use/cover (LUC) changes in Baguio city, the only American hill station in Asia and the summer capital of the Philippines. Remote sensing (RS) satellite images were used to develop the 1988, 1998, and 2009 LUC maps of the city in a Geographic Information Systems (GIS) platform. Results reveal that the city has undergone a major physical landscape transformation for the last 21 years as indicated by a rapid built-up area expansion and substantial changes in its other land uses/covers. This study also analyzes the spatial pattern of urban growth in Baguio city. Furthermore, it presents insights in planning for the future sustainable urbanization of this highly valued city.

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Keywords: land use/cover; spatio-temporal analysis; GIS, remote sensing; urbanization; hill station; Baguio city;

1. Introduction

Although the world population had historically lived in rural areas [1], urbanization was particularly rapid in the past century. People flocked to work and live in urban or metropolitan areas. And although current urban areas only account for about 3% of the earth's surface, urban expansion has resulted in significant environmental consequences such as forest degradation, landscape fragmentation, air, water and noise pollution, increase in energy consumption, decreased infiltration and an increase in surface run-off [2]. The world's urban population grew from 200 million in 1990 to about 290 million in 2000, and it is expected to be about 500 million by 2030 [3]. Such high growth rate will certainly exacerbate the existing environmental consequences of urban expansion, especially in the absence of intervention. Hence studying the spatial and temporal LUC changes might provide a significant basis for more effective land use planning that would eventually mitigate the negative consequences of urban growth, and keep the ecosystem in balance [4]. Studies show that some of the main factors that drive urban growth are physical conditions, lack of opportunities for rural development, migration into the cities, high growth rate of

* Corresponding author. Tel.: +81(29) 853-4211; fax: +81(29) 853-4211.
E-mail address: purplebee80@yahoo.co.uk

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urban population, availability of livelihood and economic opportunities, access to government services and facilities, political situations, and government plans and policies [1,5].

In some of the urban areas recently studied for LUC changes with emphasis on urban growth include Sebutal, Seimbra and Sintra-Cascais in Portugal [6,7], Kathmandu Valley in Nepal [5], Hangzhou and Shijiazhuang in China [8,9], Dhaka in Bangladesh [10], and Chillan and Los Angeles in Chile [1]. However, there has not been much information about the spatial and temporal dimensions of the LUC changes that have influenced the development of hill stations in Asia. There are about 36 hill stations in this region, and these were all established during the period of western colonization for one or more of the following main purposes: as specialized health resorts, summer capitals and administrative hubs [11]. Among the notable hill stations in Asia are Murree in Pakistan, Simla in India, Nuwara Eliya of Sri Lanka, Maymyo of Burma, Cameron Highlands in Malaysia, Bogor in Indonesia, Dalat in Vietnam, and Baguio in the Philippines [11, 12]. These hill stations have played significant roles in their respective geographic locations. However, with the continuous growth of population in the already congested lowlands, and with the changing climatic conditions and among others, some of these hill stations are beginning to experience the pressure of urbanization and resource exploitation, as in the case of Baguio city in the Philippines. Thus, this study attempts to explore the spatio-temporal pattern of LUC changes in Baguio city by using Geographic Information Systems (GIS) and Remote Sensing (RS). Specifically, it aims to detect the LUC changes between 1988 and 2009 to analyze the spatial pattern of urban expansion in the city.

2. Materials and Methods

2.1. Baguio city: the study area

Baguio city, formally established in 1909, is geographically located in northern Philippines in the Luzon Island (Fig. 1). Although it functions independently as a chartered city, Baguio, with a land area of about 57.49 km^2, is physically situated within the province of Benguet [13]. Politically and administratively, it is divided into 129 barangays (villages). As the only American hill station in Asia [11, 12] and the only hill station in the Philippines, Baguio city, the country's summer capital, has enjoyed economic, political and social prominence for more than a century [14].

Baguio city is best known for its cool climate. Situated in a region with elevation ranging from about 900 to 1,600 m asl [13], most of its developed area is at about 1,500 m [15] in a high plateau in the Cordillera mountain range of Northern Luzon. The city's temperature is, on average, 8°C lower than the temperature in the lowlands, and seldom exceeds its average annual maximum of 26°C [15]. It is generally cooler at the beginning and end of the year. The lowest temperature of 6.3°C was recorded on Jan. 18, 1961, while the city's all-time high temperature of 30.4°C was recorded on March 15, 1988 [16].

2.2. Data acquisition and processing

The list of data used in this study is presented in Table 1. Subsequent processes involved in the image processing include geometric correction, classification, accuracy assessment and change detection. The three satellite images were classified using Maximum Likelihood [17] supervised classification method in ERDAS Imagine software. The process was aided by ground truth and other ancillary data. The 1987 Philippine Constitution generally classifies the lands of the public domain in the country into agricultural, forest or timber, mineral lands and national parks [18]. Furthermore, agricultural lands of the public domain, which are the only alienable lands, may be further classified by law according to their uses such as residential, resettlement, grazing, etc. However, for the purpose of this study, the LUC maps were prepared based not only on the different land uses but also including, and in combination with, the actual land covers of the city during the time when the satellite images were captured. Thus, in this study, the

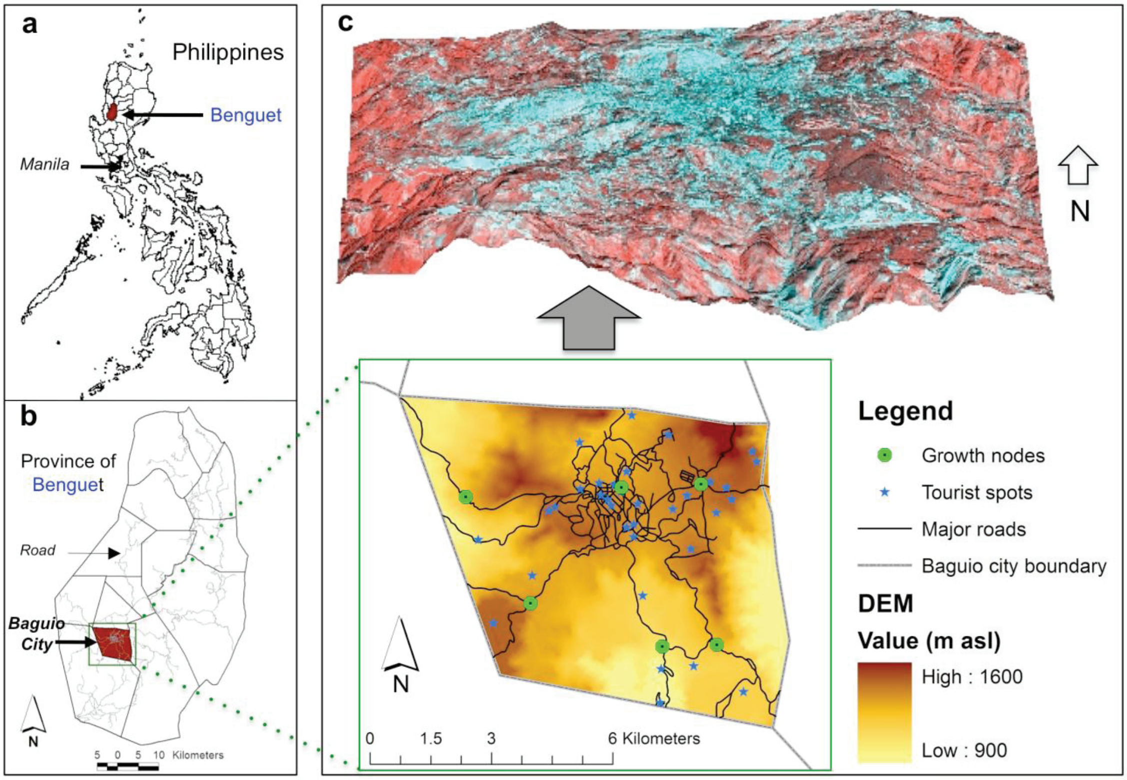

Fig. 1. Location map of Baguio city. (a) Map of the Philippines. (b) Map of the Province of Benguet showing municipal boundaries, road network and the geographical location of Baguio city. (c) A 3D map of Baguio city area created using elevation map and a 2009 ALOS-AVNIR2 satellite image (RGB: 432) (The Advanced Land Observing Satellite – Advanced Visible and Near Infrared Radiometer type 2 was developed by the Japan Aerospace Exploration Agency (JAXA)). In this standard "false color" composite, vegetation appears in shades of red, urban areas are cyan blue, and soils vary from dark to light browns. Coniferous trees appear darker red than hardwoods. Generally, deep red hues indicate broad leaf and/or healthier vegetation while lighter reds signify grasslands or sparsely vegetated areas. (d) Map of some spatial features in the study area like elevation, roads, tourist spots and growth nodes. *Data sources:* Baguio city planning office; Department of Environment and Natural Resources-Cordillera Administrative Region (DENR-CAR); JAXA.

LUC classification scheme (Table 2) was summarized and categorized into four, based on the topographic maps of the city produced by the National Mapping and Resource Information Authority (NAMRIA) in the Philippines, in conjunction with the land use/cover classification system of Anderson et al. [19].

Accuracy assessment is a process of comparing the classified results to any geographical data used as reference that are assumed to be true [20, 21]. In particular, it is a methodical way of evaluating the result of the classification with the use of reference data like, but not limited to, ground truth data, previously tested map and aerial photos [22]. In this study, the classified 1988, 1998, and 2009 LUC maps were subjected to accuracy assessment using ground truth data, topographic map and previous land use maps as references (Table 1). The widely used post-classification comparison technique was employed to detect the LUC changes in the study area by comparing the classified LUC maps. Its major advantage is the ability to detect the nature of the changes through the descriptive information generated from comparing the LUC maps [23]. In particular, the technique involved cross-tabulation and spatial overlay operations.

Table 1. Data used

Data	Date	Scale/ Resolution	Source
1. RS images			
ALOS-AVNIR2	2009	10 m	JAXA
Landsat TM	1998	30 m	USGS
Landsat TM	1988	30 m	USGS
2. Topographic map of Baguio city	1995	1:10,000	NAMRIA, DENR – CAR, Philippines
3. Land use map of BLIST	1991	1:50,000	MGS DENR – CAR, Philippines
4. Land use map of Benguet	2000	1:250,000	FMS DENR – CAR, Philippines
4. Ground truth and socio-economic data	2010 & 2011	N/A	Field survey

Table 2. Land use/cover classification scheme

Land use/cover types	Descriptions
Built-up area	Including urban, residential, industrial and institutional areas, roads, airport, and other man-made structures.
Forest	Including thickly forested areas with Pine trees and broadleaved trees.
Brushland	Including sparsely vegetated areas, bushes/scrubland, grassland, scattered trees mixed with scrubland especially in the very steep areas.
Cropland	Including areas being utilized for agricultural activities particularly for growing cash crops like vegetables and other agricultural crops. (Some grassland areas are also included in this category since separating them from cropland was not possible due to high spectral confusion).

2.3. Spatial analysis of urban growth patterns

In order to analyze the spatial urban growth patterns in Baguio city, six spatial factors, *viz.* distances to major roads, tourist spots, urban center, and growth nodes, slope, and elevation were selected. The first step involved the creation of buffer zones from the major roads, tourist spots, urban center, and growth nodes with a distance interval of 200 meters. This was followed by a zonal analysis to calculate how much built-up area was inside each buffer zone using the 1988 and 2009 LUC maps. The annual built-up area expansion rate (ABUAER) was then calculated for each buffer zone using Eq. 1.

$$ABUAER\ (\%) = \frac{BUA_{t2} - BUA_{t1}}{TA_{t2}\ (n)}\ x\ 100 \qquad (1)$$

where *ABUAER* is the annual built-up area expansion rate per zone; BUA_{t1} and BUA_{t2} are the built-up areas in each zone at time 1 (1988) and time 2 (2009) of the calculating period, respectively; TA_{t2} is the total area of each zone; and *n* is the interval in years of the calculating period.

The slope and elevation of the study area, which range from about 0 to 60 degrees and 900 to 1600 m asl, respectively, were both re-classed into 30 categories using equal interval method. This was to ensure that each class has a good range of value, and to avoid a range that is either too small or too large. In calculating the ABUAER, the same method as above was applied using the re-classed categories as zones. After all the variables had been prepared, scatter plots were produced and regression analysis was run between the ABUAER and each of the variables (using the mean values of each buffer zone and mean values of the re-classed categories). The aim was to explore the pattern of urban growth relative to each of the six variables.

3. Results and Discussions

3.1. Land use/cover changes in Baguio city

The classified LUC maps for 1988, 1998 and 2009 (Fig. 2) with overall accuracy levels of 86.86%, 87.18% and 89.10% and overall Kappa statistics of 0.8194, 0.8237 and 0.8470, respectively, show a substantial change in the landscape of the study area. Based on the statistics generated (Table 3), around 1909.26 ha (an additional 177.46% of the area in 1988) had been converted to built-up areas in the last 21 years. This increase is remarkable in such a relatively small city. Consequently, 63.28% or the equivalent of 1568.88 ha of forest cover had been lost in the same period. Around 19% of the city's cropland and 13% of its brushland no longer existed. However, upon close examination of the statistics of the major LUC conversions (Table 4 and Fig. 3), not all the forest covers were directly converted to built-up area. In fact, a large area of forests in 1988 and 1998 was converted to brushland in 1998 and 2009, respectively. During the 1988-1998 period, a large area of brushland was converted to croplands, while most of the existing croplands were converted to built-up areas. During the 1998-2009 period, however, a greater proportion of the brushland was converted directly to built-up areas. This suggests that in recent years, there had been an increasing need for residential space and other infrastructure developments like public facilities and business establishments. It indicates an escalating pressure on each of the other three LUC categories to be converted into urban/built-up area in the coming years, especially if the LUC change pattern is not disrupted.

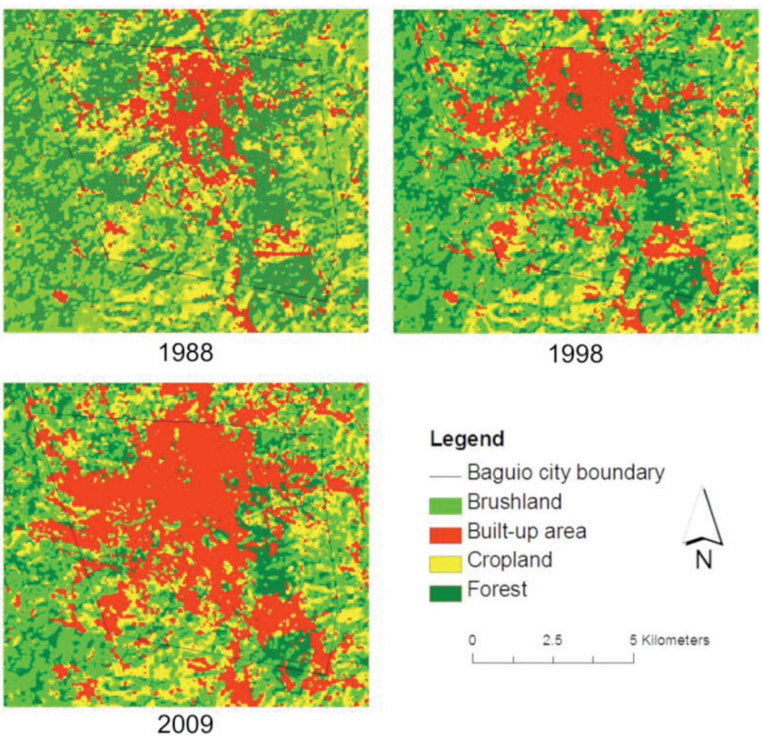

Fig. 2. Classified land use/cover maps for 1988, 1998 and 2009

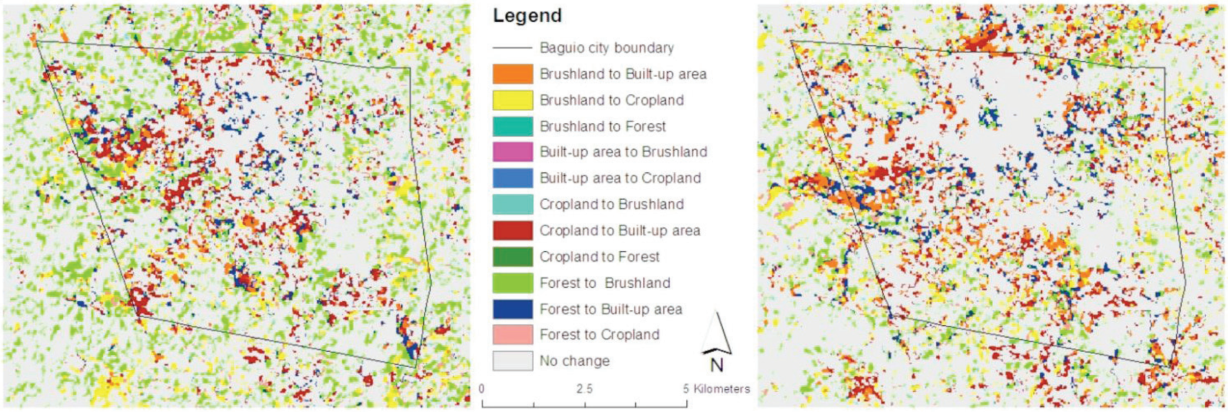

Fig. 3. Land use/cover conversions (left: 1988–1998; right: 1998–2009).

Table 3. Statistics on the land use/cover changes in Baguio city from 1988 to 2009

Land use/cover type	1988		1998		2009		Changes (ha)		
	Area (ha)	%	Area (ha)	%	Area (ha)	%	88–98	98–09	88–09
Built-up area	1075.86	18.72	1972.71	34.32	2985.12	51.94	896.85	1012.41	1909.26
Forest	2479.23	43.14	1519.92	26.45	910.35	15.84	-959.31	-609.57	-1568.88
Brushland	1264.32	22.00	1477.35	25.71	1102.59	19.18	213.03	-374.76	-161.73
Cropland	927.81	16.14	777.24	13.52	749.16	13.04	-150.57	-28.08	-178.65
Total	5747.22	100.00	5747.22	100.00	5747.22	100.00			

Table 4. Major land use/cover conversions in Baguio city from 1988 to 2009

1988–1998			1998–2009		
From class	To class	Area (ha)	From class	To class	Area (ha)
Forest	Built-up area	279.81	Forest	Built-up area	323.37
	Brushland	576.63		Brushland	239.85
	Cropland	111.42		Cropland	60.12
Brushland	Built-up area	208.71	Brushland	Built-up area	405.72
	Cropland	183.69		Cropland	213.66
Cropland	Built-up area	419.49	Cropland	Built-up area	292.32
	Brushland	30.96		Brushland	15.03
Other conversions		19.71	Other conversions		22.77
Total		1830.42	Total		1572.84

Results revealed that among the changes in the LUC of the city, the increase in built-up area was found to be the most obvious and noteworthy. It changed the landscape of the city. The spatio-temporal changes in other LUC had also been influenced by the expansion of built-up areas, directly and indirectly. During the study period (1988–2009), although built-up area expansion was tremendous, it had not been properly managed. During the early 20th century, building of houses in the city by the locals was even encouraged and inspired by the then city officials [14, 24]. However, this has not been the case for the last few decades or so. With a population of 5,464 in 1918 [13], the city is now a home to 301,926 people [25], resulting in a population density of 5,252 persons per km^2. This rapid population increase far outstripped the city's designed ceiling of 25,000 people only [24, 26, 27]. Hence, Baguio, a relatively small city, of just 57.49 km^2, now supports about 12 times more than its carrying capacity, or even more during daytime, when its population doubles the official census to around 700,000 [28]. More people means more demand for housing, increased generation of wastes, and greater need for public services and facilities.

Due to the ever-increasing demand for better living conditions, Baguio city's carrying capacity, in terms of natural, physical and socio-economic resources, has reached critical status. Although the city's population growth rates of 5.30%, 4.78%, 2.5% and 2.80% for the past five census periods from 1980–2007 [25, 29] show a general decreasing trend, the current population growth rate of just below 3% is still relatively high, considering the size and the capacity of the city to provide the necessary services. The 0.30% increase in the last two census periods also indicates an increasing trend, which might again continue in the future, especially if the issue on population growth is not properly addressed.

Furthermore, despite the ratification and implementation of Republic Act 705, otherwise known as Revised Forestry Code of the Philippines, which was aimed at ensuring full protection and management of the country's forest resources, deforestation during the last two decades has not stopped completely. It has also been reported that deforestation (including forest conversion) caused by urbanization [30, 31, 32] has been contributing to the deterioration of air quality in the city [32].

Results of this study also reveal that urbanization is indeed a major factor in influencing the spatial and temporal changes of the overall landscape of Baguio city. The development and availability of basic and essential urban services and facilities over the years have helped transform the city into what it is today: the summer capital of the country, a major educational, trade, tourist, administrative, and recently an emerging industrial and health service center north of Metro Manila [14]. This scenario presents a cyclical process of growth and development of the city. In the process, population growth has influenced the city's urbanization, eventually helping in its growth and development as a city. This in turn has attracted more people to the city, which offers more services and opportunities. However, due to the limited space and physical resources the city has at its disposal, continuous rapid population growth and uncontrolled urban sprawl have been pushing the city towards unsustainable state of urbanization.

3.2. Spatial analysis of urban growth patterns

Fig. 4 presents the scatter plots of the six spatial factors and their respective ABUAER. Of these six variables, only one variable (distance to urban center) shows a very poor linear relationship with the ABUAER. As mentioned earlier, this section aims to explore only the pattern of urban growth relative to each of the six variables. Thus, the variables are plotted and analyzed individually against their respective ABUAER. The results reveal that distance to major roads has the highest coefficient of determination (R^2) of 0.859 with a p-value of 0.000, indicating a good and highly significant linear relationship with ABUAER. This is followed by the distance to growth nodes and slope with both showing a highly significant relationship with their respective calculated ABUAER. Distance to tourist spots and elevation also have significant relationships with their respective computed ABUAER.

The results reveal that distance to the main roads has a highly significant relationship with its calculated ABUAER (Fig. 4a). Areas closer to the main roads have relatively higher ABUAER. This implies the significance of accessibility as a spatial determinant of built-up area expansion in the city. The results also show that the distance to tourist spots has a significant relationship with its computed ABUAER (Fig. 4b). In fact, tourism is one of the city's industries. Both the government and local people benefit from this industry. It has been a part of everyday living of the local people in the city. Both big businesses like hotels and restaurants, and small enterprises like souvenir shops benefit from tourism activities.

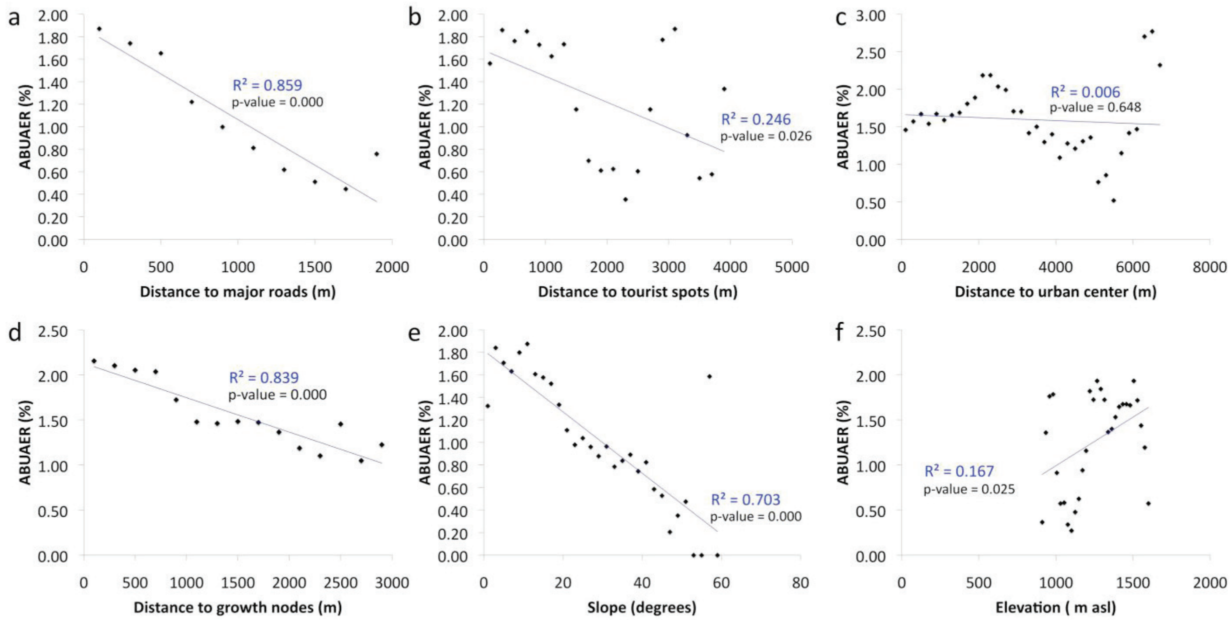

Fig. 4. Scatter plots of the annual built-up area expansion rate (ABUAER) (1988–2009) and the six spatial factors. Some information about these spatial factors can be seen in Fig. 1.

In contrast, Fig. 4c shows a quite different trend. The results show a statistically poor and not significant relationship between the distance to the urban center and its calculated ABUAER. This means that ABUAER is statistically not dependent on the relative location of the urban center. In relation to this however, Figs. 1c, 2 and 3 show that built-up areas have been expanding outward from the city core. We believe that this scenario has been driven by the decrease of available space near the central business district (CBD) because the town center is already fully built up while the demand for space continues to increase. The regression depicted in Fig. 4c, when taken as a whole, is not statistically significant. However, clearer trends are discernible when the areas up to 2 km from the urban centre, and the areas from 2 to 6 km away are considered separately. Since ABUAER is a proportional measure of *new* development, there is little space left over for new development in the town center itself that is already fully built up. It can be seen in Fig. 4c that as one moves away from the urban center (from 0 to 2 km), there is a positive trend in ABUAER as space for new building becomes available. Farther than 2 km, however, it becomes increasingly less desirable to build too far from the town center, and the trend becomes negative.

Results further reveal that distance to growth nodes and its calculated ABUAER have a highly significant relationship (Fig. 4d). The graph suggests that significant fraction of built-up areas expansions have been around the growth nodes identified by the city government. Furthermore, the result indicates that ABUAER is also associated with slope as indicated by a highly significant relationship (Fig. 4e). Slope has been a significant factor affecting the spatial pattern of urban expansion in the city. Generally, people prefer to live on flat or gentle terrain. However, although relatively lower, the ABUAER in steeper slopes (i.e. > 20 degrees) may also indicate that due to rapid built-up area expansion, people are "forced" to occupy such areas without taking into account the imminent danger of settling there. This result corroborates with what has been observed in Fig. 1 and during the field survey that built-up areas are all over the city, expanding even onto sloping areas.

Finally, elevation also has a significant association with its computed ABUAER as indicated by, this time, a positive relationship (Fig. 4e). We believe that this scenario has also been driven by the decreasing available space in the city proper situated at approximately 1500m asl elevation. It is interesting to note that ABUAER is relatively higher in areas of higher elevation than the lower areas. Perhaps, this is also affected by slope since topography in lower areas is relatively less gentle (Figs.1c and 1d). It could also be due to the popular preference for cool temperatures, which cannot be enjoyed in lower areas (i.e. elevation of 850m asl vs. 1500m asl, the latter has a relatively much cooler and conducive temperature). Baguio city, nestled on a 1500m high plateau in the Cordillera mountain range of Northern Luzon, provides a conducive and relatively cool climate, which has been the most valued physical asset of the city.

4. Conclusions

This study not only explores the spatio-temporal pattern of LUC changes in Baguio city, but also confirms the applicability and effectiveness of RS and GIS in this field of study. A significant finding is that the city has undergone a major physical landscape transformation in the last 21 years as indicated by an almost 3-fold increase in its built-up area at the expense of the other land uses/covers. The result of the spatial analysis of the urban growth patterns in the city gives a bird's eye view on how each spatial factor is associated with the variability of ABUAER in the city. Through the years, rapid population growth, the availability of basic and essential urban services, facilities and economic opportunities have transformed this hill station into a highly urbanized city. Being situated on the main island of Luzon, the city's accessibility has been a significant factor in its physical transformation. For example, people from the lowlands and other cities like the city capital of the Philippines, Manila, have a very good access to this great hill station. Furthermore, its cool climate coupled with the fresh green and peaceful environment of Baguio, not found elsewhere in the Philippines and for which the city is noted, make it a favorite destination for many, especially those who wish to relax and escape from the excessive heat of the lowlands [14]. This is the city's strongest selling point. Besides being a very popular tourist destination, it is also a gate- way to other tourist hot spots in the north. Hence, Baguio city also plays a very strategic role in the region's tourism industry. Nevertheless, such transformation is exerting pressure on the city's amenities, resources and natural environment. Good governance and proper planning are critical for its sustainable urban development. In general, this study explores the trend in the physical landscape transformation of a sub-tropical hill station, and presents insights that could be used in planning for the future development of Baguio city towards sustainable urbanization.

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